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EXPERIMENTAL STUDY OF NANO SILICA AND SILICA FUME CONCRETE COLUMN SUBJECTED TO CORROSION

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ABSTRACT

The contemporary study scrutinizes the use of nano silica and silica fume in concrete. Nano silica and silica fume are highly pozzolanic nature. To improve the mechanical properties of concrete for M30 and M40 with the use of silica fume (5%, 7.5 %, 10 %, 12.5 %) and nano silica (1%, 2%, 3%, 4%) as the partial replacement of cement were studied. Corrosion of steel in ordinary concrete is continually growing and causes problem. This affects the performance and durability of concrete structural elements. Normally concrete act as a physical barrier to the aggressive environment for the reinforcing steel because of its high alkalinity. The corrosion of reinforcing steel in ordinary concrete occur due to lack of quality control in mixing, planning and consolidation an entrapping of air in the concrete, resulting in reliability permeable concrete. When the structures are exposed to corrosive environment, premature failure of R.C columns due to corrosion leads to ultimate structural failure. In order to overcome this situation to an exent possible, Corrosion resistance for conventional and nano silica and silica fume concrete column were studied by using accelerated corrosion technique.

Key words: Nano silica, Silica fume, Compressive strength, Split tensile strength, Flexural strength, Corrosion resistance for column.

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1. INTRODUCTION

Silica fume is an extremely fine material with the particle size ranging from 1 μm in diameter. Silica fume have high silica content and also it is an efficient pozzolanic material. Silica fume is supplemented to the concrete to enhance its properties, such as compressive strength, bond strength, and abrasion resistance. When silica fume is added in to the concrete it reduces the permeability of concrete and it protects the reinforced concrete structure from corrosion to a greater extent.

Nowadays, Nano technology is widely used in entire line of work. Concrete is exhaustible material in construction industry and want to develop the properties of concrete. Nano particles are added to the concrete to enhance the mechanical properties of concrete than the conventional concrete. Nano silica is the first product that replaced the micro silica. Nano silica improves the bulk properties of concrete and reduces the setting time of concrete than the conventional concrete. Nano silica has more pozzolanic nature. Nano silica is extremely fine particle than the silica fume and it reduces the pores of concrete and also to reduce the permeability of concrete therefore it leads to improvement in the durability of concrete. When Nano silica is added in to concrete, which protect the reinforcing steel from corrosion

Corrosion of reinforced concrete structure is a most important drawback and it affects the durability of structure. Corrosion occur in the steel depends upon the water cement ratio, permeability of concrete, chloride ions, Ph value and carbonation. Corrosion also produces the pit in the reinforcing steel, it also reduces weight of the reinforcing steel and it reduces strength of the reinforcing steel. **Q.Ye et al (2001)** [1] Addition of the micro silica and the nano silica as the replacement of cement had been studied experimentally. The compressive strength and the electrical resistivity value were higher than the conventional concrete. **Nili Eshani et al (2008)** [2] investigated the micro silica and silica fume as the replacement of cement had the advantage effect on the performance of concrete. **R.Siddique et al (2011)** [3] Addition of the micro silica as the replacement of cement has been studied in the experiment. It improves the durability of concrete than the conventional concrete and it protects the reinforced concrete structure from corrosion. **Verma Ajay et al (2012)** [4]**, i**nvestigated the micro silica (MS) were replaced in to the cement and the strength of concrete were compared with the conventional concrete. The strength of silica fume concrete more than 25% than the conventional concrete. Silica fume were added in to concrete to reduce the void in concrete and also to reduce the capillary rise of water in concrete. **Mohammad Reza Zamani Abyaneh, et al (2013)** [5] investigates the Micro silica and Nano-silica which are added in to the concrete and it shows higher compressive strength and also less water absorption and more electrical resistance than the conventional concrete. **Ahmed et al** [6] studied the effect of reinforcement corrosion on cracking of concrete cover by the impressed current technique.

2. MATERIALS USED

The physical properties of material used in the study is illustrated below. The material such as nano silica and silica fume were obtained from retailers and their properties were predetermined.

2.1. CEMENT

Ordinary Portland cement of grade 53 with properties confirming with IS 12269-2009 were used. The properties of cement are shown in Table 2.1.

Table 2.1 Properties of cement

S. No	Property	Results
1	Specific gravity	3.14
2	Fineness modulus	6

2.2. FINE AGGREGATE

The sand used conforms to grading zone II of IS 383:1970. The properties of fine aggregate are shown in Table 2.2.

Table 2.2 Properties of fine aggregate

S. No	Property	Result
1	Specific gravity	2.67
2	Fineness modulus	3.01
3	Bulk density	1600 kg/m^3

2.3. COARSE AGGREGATE

The coarse aggregate were used from the confined quarry. The properties of fine aggregate are shown in Table 2.3.

Table 2.3 Properties of fine aggregate

S. No	Property	Result
1	Specific gravity	2.74
2	Fineness modulus	4.30
3	Bulk density	1750 kg/m^3

2.4. SUPER PLASTICIZERS

CONPLAST was used for M30 and M40 Grade of concrete. While preparing the concrete the properties of CONPLAST are shown in Table 2.4.

Table 2.3 Properties of CONPLAST

S. No	Property	Result
1	Colour	Dark brown liquid
2	Chloride content	Nil
3	Air entrainment	Less than 1.5 %

2.5. SILICA FUME

The silica fume satisfies the requirement IS: 15388:2003. The silica fume was ultra fine particle and the colour of the silica fume was white. The specific gravity of silica fume was 2.61.

2.6. NANO SILICA

The size of the nano silica particle was 5-30 nm and the specific gravity of nano silica was 1.31.

3. MIX DESIGN

Mix design was carried out for M30 and M40 grade. Different proportions of silica fume and nano silica are added in to the concrete mixture. The various mix proportions used in the present study are given in Table 3.1 and Table 3.2. Nano-particles and silica fume are not easy to

distribute uniformly due to their high surface energy. Therefore, particles were stirred in water, and then they were added to the mixture.

Table 3.1 Mix proportions for M30 grade concrete

S. No	Percentage of Nano Silica	percentage of Silica fume	Cement Kg/m^3	Sand Kg/m^3	C.A Kg/m^3	Water Kg/m^3	Super Plasticiser %
1	0	0	417.00	720	1180	186	0
2	1	5.00	388.00	720	1180	140	21
3	2	7.50	372.46	720	1180	140	21
4	3	10.00	359.00	720	1180	140	21
5	4	12.50	346.78	720	1180	140	21

Table 3.2 Mix proportions for M40 grade concrete

S. No	Percentage of silica fume	percentage of Nano silica	Cement Kg/m^3	Sand Kg/m^3	C.A Kg/m^3	Water Kg/m^3	Super plasticiser %
1	0	0	437.00	690	1020	186.	0
2	5.00	1.00	419.00	690	1020	140	21
3	7.50	2.00	396.25	690	1020	140	21
4	10.00	3.00	381.40	690	1020	140	21
5	12.50	4.00	368.00	690	1020	140	21

4. EXPERIMENTAL INVESTIGATION

The experimental investigation is carried out to determine the mechanical properties of concrete for M30 and M40 grade of concrete with nano silica and silica fume as different replacement levels with ordinary Portland cement and also to determine percentage of corrosion and corrosion current density for conventional concrete column and nano silica fume concrete column for M40 grade.

4.1. COMPRESSIVE STRENGTH

According to IS 516:1959, 12 numbers of cubes for conventional concrete and 48 numbers of cubes for nano silica and silica fume were casted. After a day of casting cubes are removed from the moulds and placed under curing for testing the compressive strength at an age of 14 days and 28 days respectively. The test results are considered as an average of 3 cubes at each time of testing. The compressive strength for M30 and M40 was shown in Table 4.1 and Figure 4.1.

Table 4.1 Compressive strength of concrete with nano silica and silica fume at 14 and 28 days for M30 grade and M40 grade

S. No	Grade of concrete	Percentage of Nano silica	Percentage of silica fume	Compressive strength 14 days(N/mm^2)	Compressive strength 28 days(N/mm^2)
1	M30	0	0	28.08	36.21
		1	5.00	36.94	41.02
		2	7.50	42.33	46.96
		3	10.00	39.04	43.70
		4	12.50	38.32	42.00
2	M40	0	0	37.56	45.22
		1	5.00	45.88	50.26
		2	7.50	49.79	55.77
		3	10.00	46.38	54.02
		4	12.50	45.73	51.26

The Table 4.1 shows the compressive strength of concrete for M30 grade and M40 grade. The maximized compressive strength was attained by using 2 % of nano silica and 7.5% of silica fume as the replacement of cement. Further addition of nano silica and silica fume resulted in degradation of strength in concrete. Hence in this research it is found that optimum percentage of nano silica is 2% and silica fume is 7.50 %.

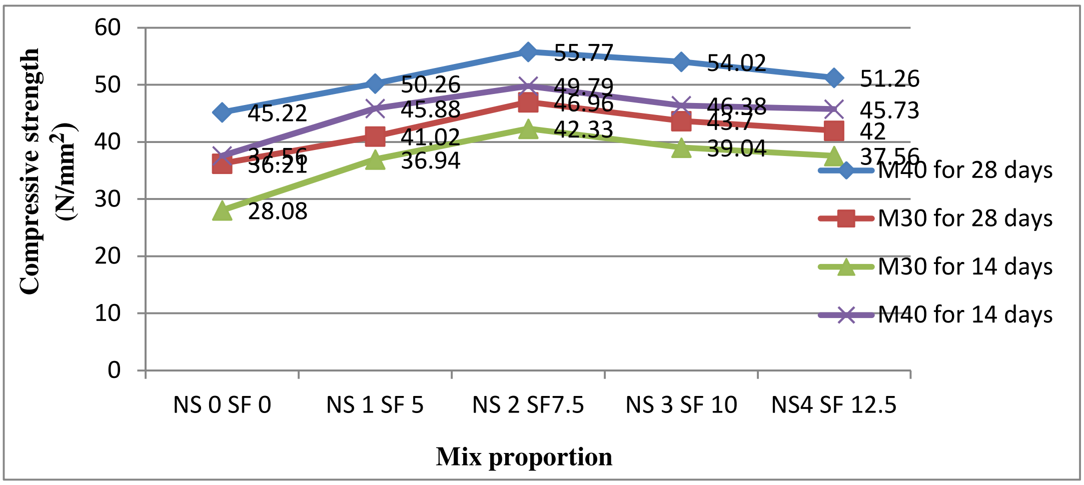

Figure 4.1 Comparison of compressive strength of concrete with nano silica and silica fume for M30 grade and M40 grade

4.2. SPLIT TENSILE STRENGTH

For split tensile strength, 12 numbers of cylinders for conventional concrete and 48 numbers of cylinders for nano silica and silica fume were casted. After a day of casting cubes are removed from moulds and placed under curing for testing of split tensile at an age of 14 days and 28 days respectively. The test results are considered as an average of 3 cylinders at each time of testing. The split tensile strength for M30 and M40 was shown in Table 4.2 and Figure 4.2.

Table 4.2 Split tensile strength of concrete at 14 and 28 days for M30 grade and M40 grade

S. No	Grade of concrete	Percentage of Nano silica	Percentage of silica fume	Split tensile strength 14 days (N/mm²)	Split tensile strength 28 days (N/mm²)
1	M30	0	0	2.63	2.93
		1	5.00	3.10	3.45
		2	7.50	3.30	3.78
		3	10.00	3.18	3.65
		4	12.50	3.12	3.58
2	M40	0	0	3.01	3.42
		1	5.00	3.65	4.12
		2	7.50	4.12	4.56
		3	10.00	4.04	4.49
		4	12.50	3.95	4.49

The Table 4.2 shows the split tensile strength of concrete for M30 grade and M40 grade. The maximized split tensile strength was attained by using 2 % of nano silica and 7.5% of silica fume sa the replacement of cement. Further addition of nano silica and silica fume which causes the degradation of strength in concrete. From split tensile strength it was found that optimum percentage of nano silica is 2% and silica fume is 7.50 %.

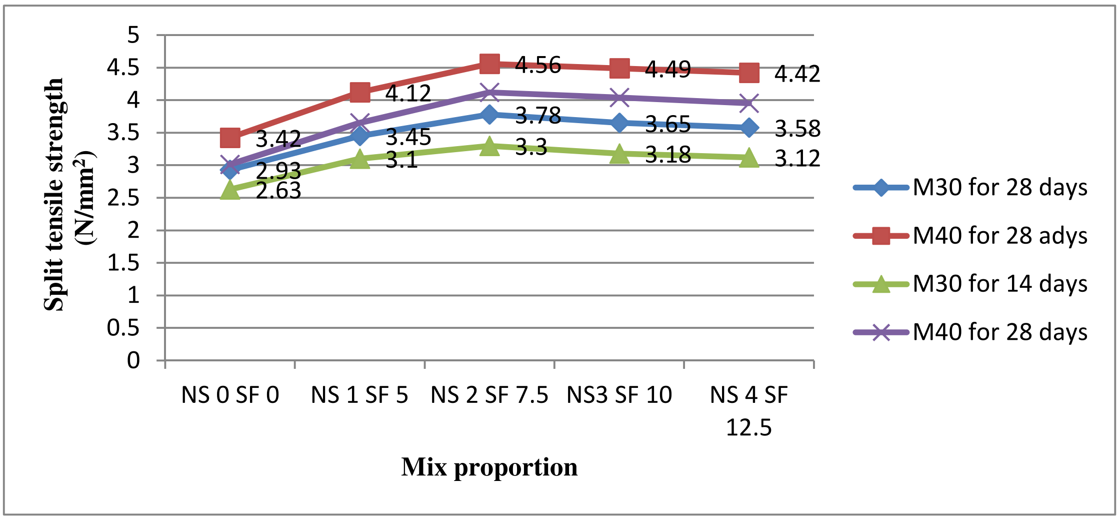

Figure 4.2 Comparison of split tensile strength of concrete with nano silica and silica fume for M30 grade and M40 grade

4.3. FLEXURAL STRENGTH

For flexural strength, 12 numbers of beam for conventional concrete and 48 Numbers of beam for nano silica and silica fume were casted. After a day of casting cubes are removed from moulds and placed under curing for testing of flexural at an age of 14 days, and 28 days respectively. The test results are considered as an average of 3 beam at each time of testing. The flexural strength for M30 and M40 was shown in Table 4.3 and Figure 4.3

Table.4.3 Flexural strength of concrete at 14 and 28 days for M30 grade and M40 grade

S. No	Grade of concrete	Percentage of Nano silica	Percentage of silica fume	Flexural strength 14 days (N/mm^2)	Flexural strength 28 days (N/mm^2)
1	M30	0	0	2.98	3.36
		1	5.00	3.23	3.70
		2	7.50	3.60	4.01
		3	10.00	3.54	3.94
		4	12.50	3.48	3.87
2	M40	0	0	3.60	4.00
		1	5.00	3.90	4.34
		2	7.50	4.38	4.87
		3	10.00	4.32	4.81
		4	12.50	4.28	4.76

The Table 4.3 shows the flexural strength of concrete for M30 grade and M40 grade. The maximized flexural strength was attained by using 2 % of nano silica and 7.5% of silica fume as the replacement of cement. Further addition of nano silica and silica fume which causes the degradation of strength in concrete. By conducting the flexural strength, it is found that optimum percentage of nano silica is 2% and silica fume is 7.50 %.

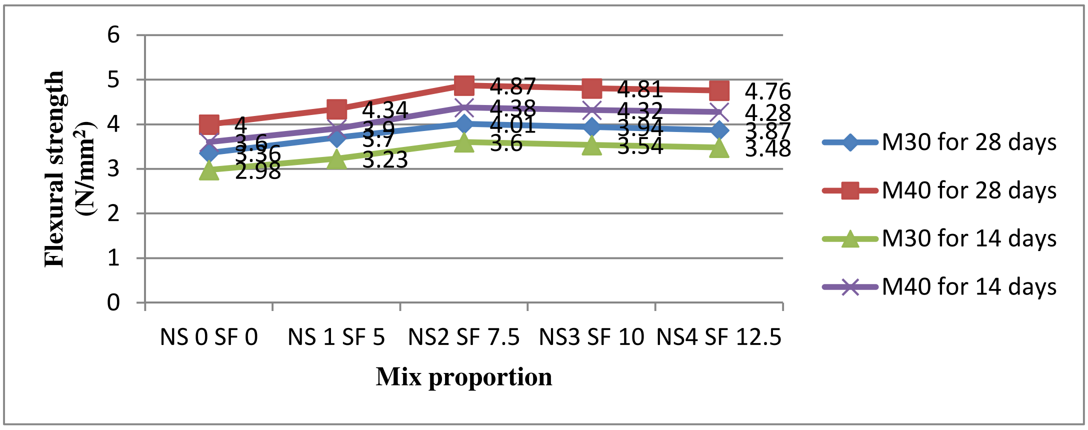

Figure 4.3 Comparison of flexural strength of concrete with nano silica and silica fume forM30 and M40 grade

6. ACCLERATOR CORROSION TECHINQUE

The set up for accelerating reinforcement corrosion was (120×120×1000 mm) reinforced concrete columns having 12 mm diameter reinforcement bar is provided. The effective cover of the column was 20 mm. 8 mm ties are provided with the spacing of 100mm throughout the length of the bar. The electrical wires were soldered to the reinforcement bars before placing the concrete in the column moulds. Copper wires are connected to the reinforcement for monitoring the corrosion rate. The columns are immersed in water to ensure the full saturation condition. The water containing the 5% of Nacl solution. The steel bar act as the anode and the stainless plate is placed in the column, which act as the cathode. The AC transformer of 64Volts and 10Amps was used as power source. The AC output was converted to DC supply with the help of rectifier and the capacitor. One set of wire was connected to anode and the other set of wire was connected to cathode source. The corrosion produced in the bar can be found by

applying current in the reinforced structure. The rate of corrosion induced in the reinforcement was found by Faradays law. The set up for accelerating reinforcement was shown in Figure 6.1

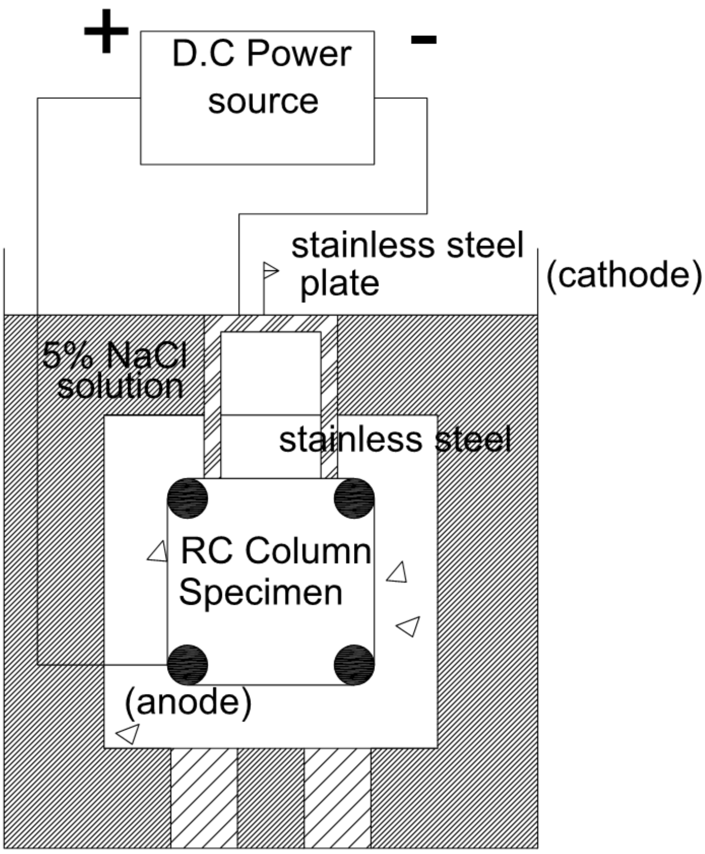

Figure 6.1 Shows set up for accelerating corrosion for column

7. CALCULATION OF CORROSION INDUCED IN REINFORCEMNT

The percentage of corrosion induced in the conventional concrete column and nano silica and silica fume concrete column was shown in Table 7.1 and Figure 7.1. The degree of corrosion was found by percentage of weight loss.

Table 7.1 Shows the percentage of corrosion for conventional concrete column and nano silica and silica fume concrete column for M40 grade

S. No	Description of column	Percentage of corrosion	No. Of days
1	Conventional concrete column	1.15	7
		3.90	14
		6	21
2	Nano silica and silica fume concrete column	0.72	7
		2.80	14
		4.64	21

The Table 7.1 shows that percentage of corrosion induced in the conventional concrete column is more compared to the nano silica and silica fume concrete column. The number of days increases the percentage of corrosion induced in the reinforcement was increased for both conventional column and the nano silica and silica fume concrete column.

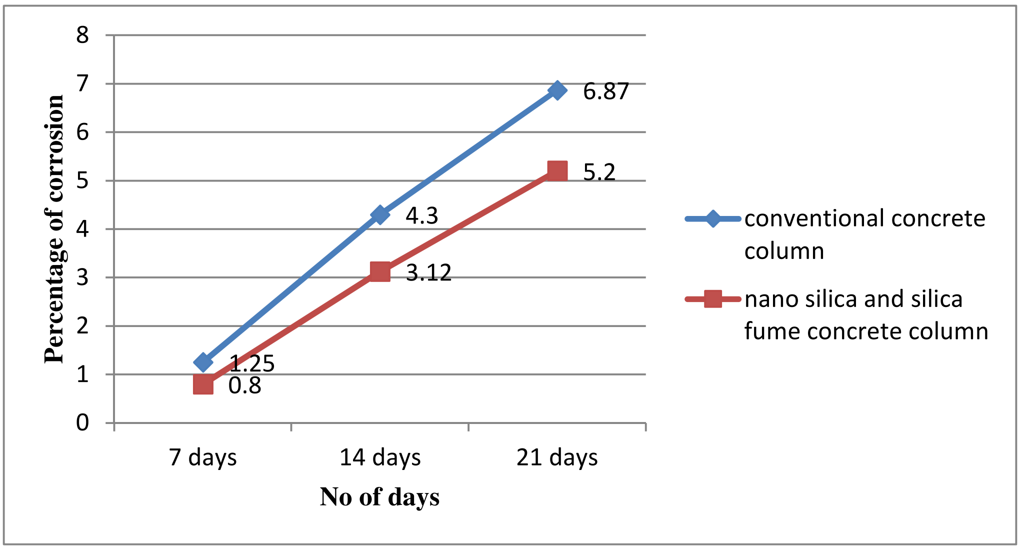

Figure 7.1 Shows the percentage of corrosion for nano silica and silica fume concrete column and conventional concrete column for M40 grade

8. CORROSION CURRENT DENSITY MEASUREMENT

The current density was measured for the conventional concrete column by using the Faradays law was shown in Table 8.1.and Figure 8.1.

Table 8.1 Corrosion current density for conventional concrete column for M40 grade

S. No	No of days	Percentage of corrosion	Corrosion Current density (mA/cm^2)
1	7	1.25	1.10
2	14	4.30	1.33
3	21	6.87	1.68

The Table 8.1 shows the corrosion current density for conventional concrete column for M40 grade. The percentage of corrosion increases in the column, the corrosion current density for conventional column also increases.

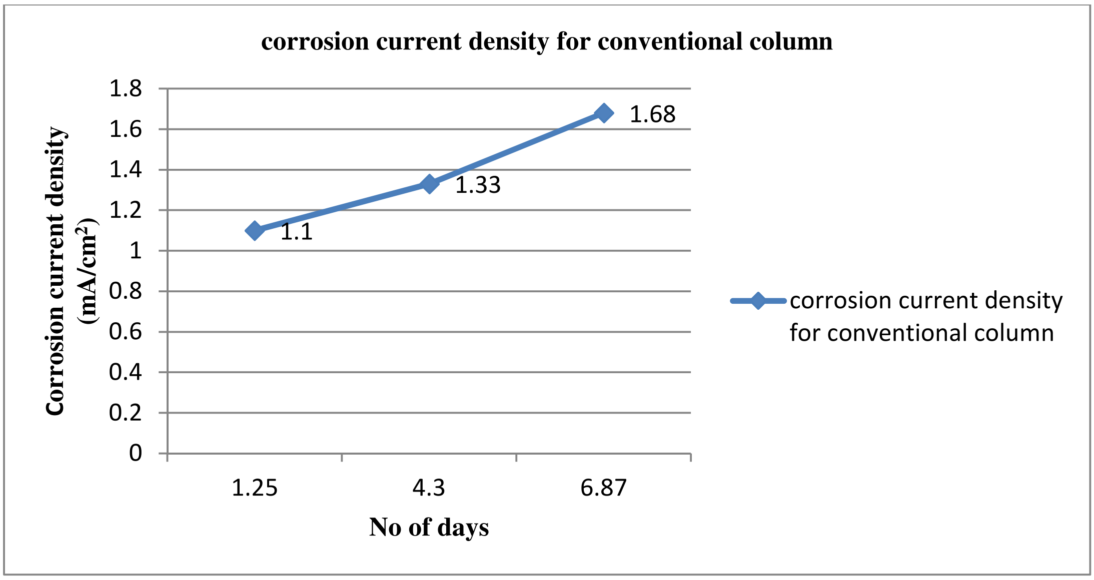

Figure 8.1 Corrosion current density for conventional concrete column for M40 grade

The current density was measured for the nano silica and silica fume concrete column by using the Faradays law was shown in Table 8.2 and Figure 8.2

Table 8.2 Corrosion current density for nano silica and silica fume concrete column for M40 grade

S. No	No of days	Percentage of corrosion	Corrosion current density (mA/cm^2)
1	7	0.80	0.64
2	14	3.125	0.86
3	21	5.20	0.95

The Table 8.2 shows corrosion current density for nano silica and silica fume concrete column for M40 grade. The percentage of corrosion increases in the column, the corrosion current density for nano silica and silica fume column also increases.

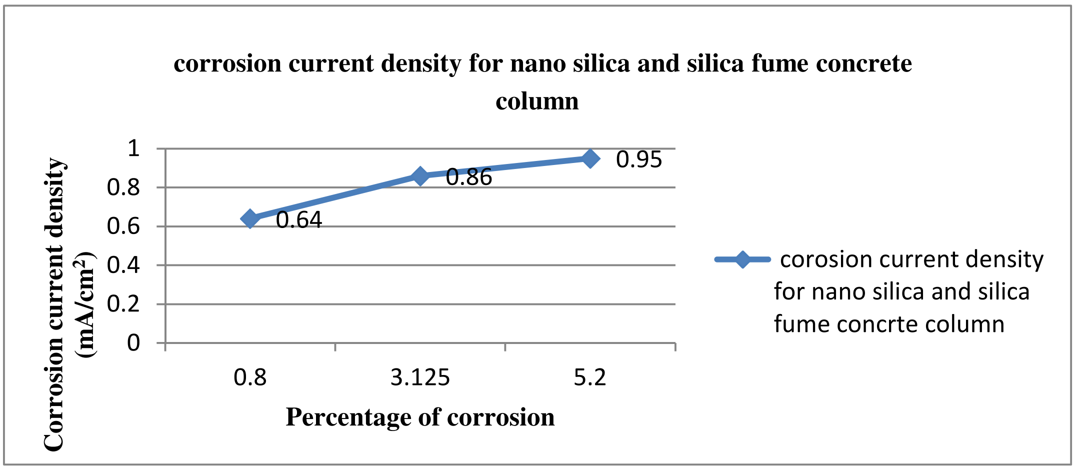

Figure 8.2 Corrosion current density for nano silica and silica fume concrete column for M40 grade

8. SUMMARY OF EXPERIMENTAL WORK

- The replacement of cement with 2 percentage of nano silica and 7.5 percentage of silica fume increase the compressive strength for M30 grade was 22.891 percentage and for M40 grade was 18.91 percentage more than the conventional concrete. The replacement of cement with 2 percentage of nano silica and 7.5 percentage of silica fume increase the split tensile strength for M30 grade was 22.44 percentage and for M40 grade was 25 percentage more than the conventional concrete.
- The replacement of cement with 2 percentage of nano silica and 7.5 percentage of silica fume increase the flexural strength for M30 grade was 16 percentage and for M40 grade was 17 percentage more than the conventional concrete.
- The addition of silica fume more than 7.5 percent and addition nano silica more than 2 % causes the degradation of strength in concrete.
- The percentage of corrosion occur in the nano silica and silica fume concrete column is less compared to the conventional concrete column.
- The corrosion current density for nano silica and silica fume concrete column is less compared to the conventional concrete column.

9. CONCLUSION

From this study the replacement of cement with nano silica and silica fume increases the mechanical properties of concrete more than conventional concrete. The electrical resistivity of nano silica and silica fume concrete column is more, therefore the corrosion occur in the nano silica and silica fume concrete column is less. The electrical resistivity of conventional concrete column is less, therefore the corrosion occur in the conventional concrete column is more. While adding nano silica and silica fume in the concrete, increases the corrosion resistance in concrete than the conventional concrete and also to increases the durability of concrete than the conventional concrete.

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